Radiosurgery/Biology Laboratory

Orthogonal Limited Arc Scan Combinations Reconstructed Iteratively to Reduce Photon Starvation Artifacts Caused by Pedicle Screws in CBCT

Michael C. Hermansen, Alireza Entezari, Scott Banks, and Frank J. Bova

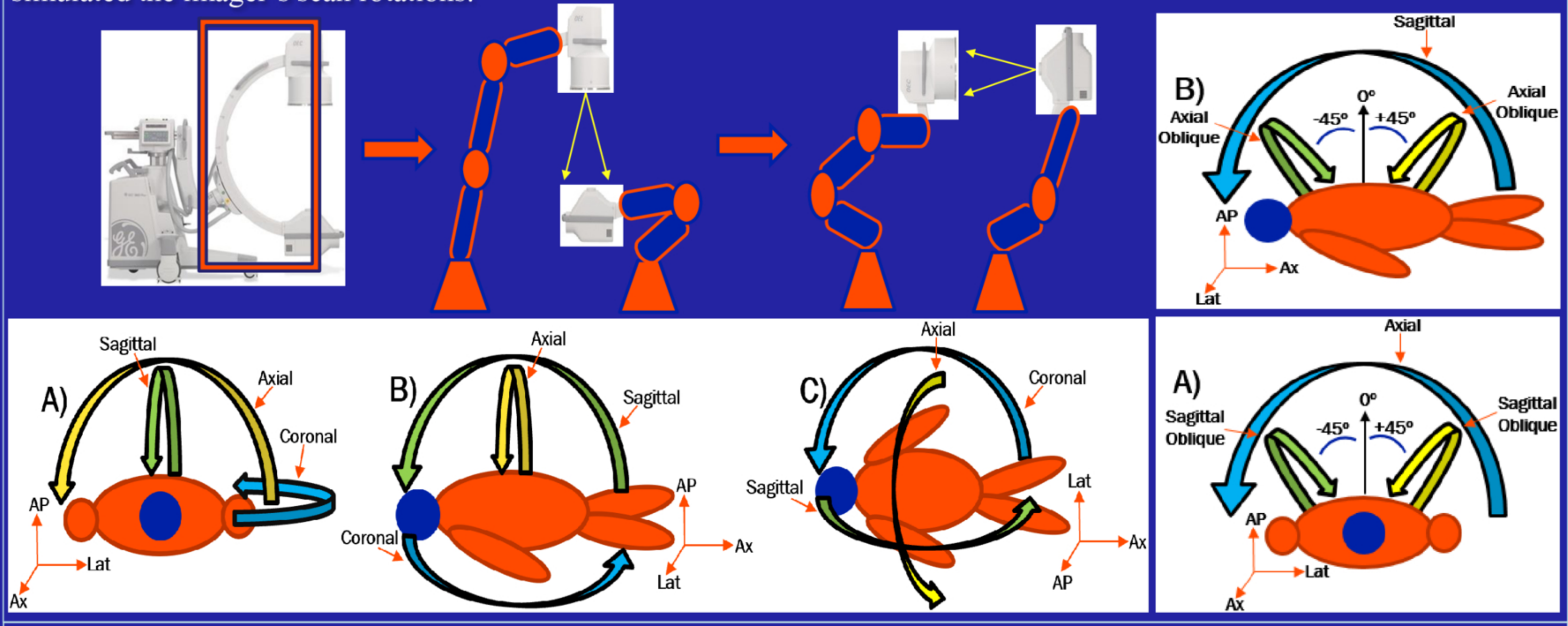
Department of Neurosurgery, University of Florida, Gainesville, Florida

ABSTRACT:

A novel robotic imager with the image receptor and x-ray source mounted on separate opposable arms allowing six degrees of freedom of movement opens the investigation of the intraoperative image acquisition of pedicle screws via limited angle axial and non-axial rotations.[1] When compared to standard axial imaging, non-axial rotations acquire projections that limit photon attenuation by the pedicle screws. Non-axial rotation projections can avoid highly attenuated photon trajectories, thereby reducing photon starvation artifacts. To avoid patient collisions with the imager, limited arc lengths were investigated. Orthogonal limited arc scan combinations (OLASCs) were reconstructed iteratively using adaptive-steepest-decent projections on convex sets (ASD-POCS). Pedicle screws were added to examine OLASC's affects on photon starvation artifact.

BACKGROUND:

UF's Robotic Imager: The removal of the obstructive gantry connection provides the physician with more space, and with six degrees of freedom with which to acquire limited arc non-axial scans. Digitally reconstructed radiographs (DRRs) simulated the imager's scan rotations.



MATERIALS:

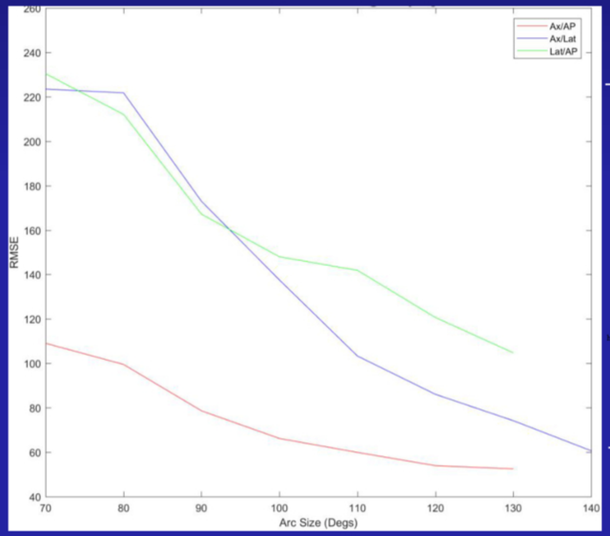
- CBCT Phantoms
  - Catphan
  - Anatomical
    - Ballistic Gel
    - Pig Vertebrae
    - Pedicle Screws
- Virtual X-Ray Simulator
- MATLAB®
  - TIGRE[2]

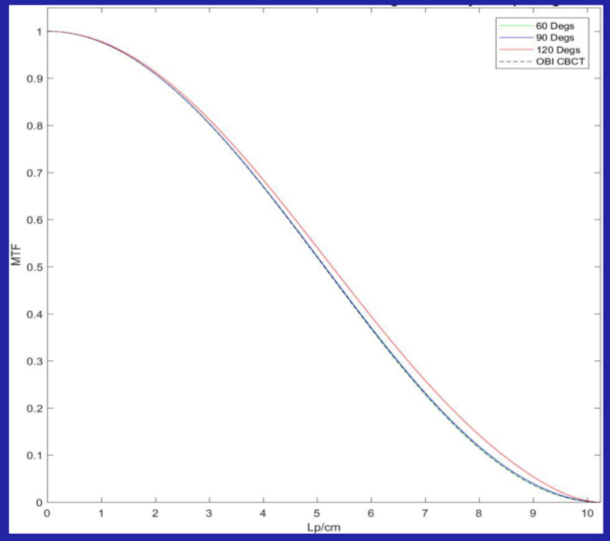
METHODS:

1. Acquire CT or CBCT of phantom
2. Define OLASC projections' geometries
   - Trajectories, arc size, and projection density
3. Generate DDRs via Virtual X-Ray Simulator
4. Reconstruct 3D volume via iterative ASD-POCS
   - TIGRE in MATLAB®
5. Image analysis
   - Root mean square error (RMSE) and Modulated Transfer Function (MTF)
   - Visual evaluation of metal artifacts

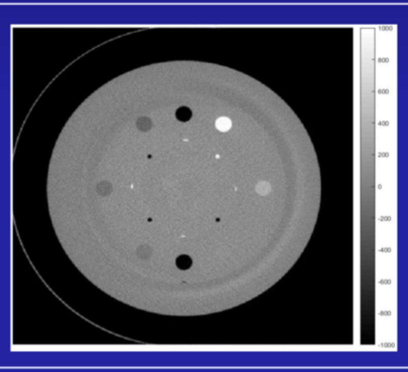
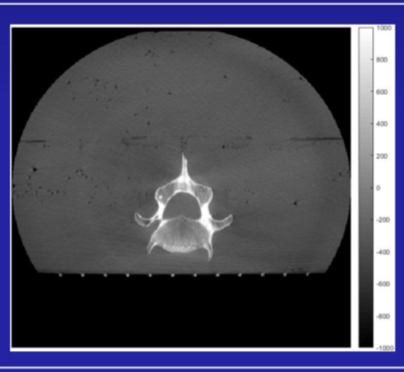
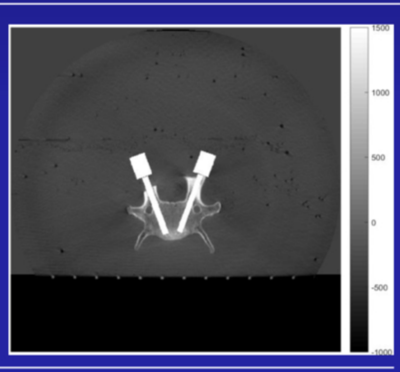
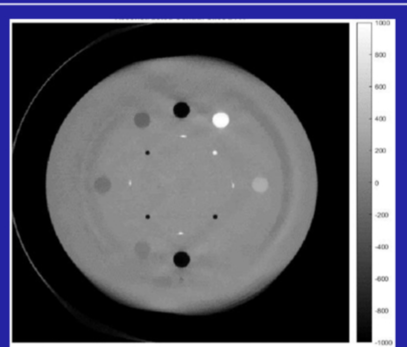
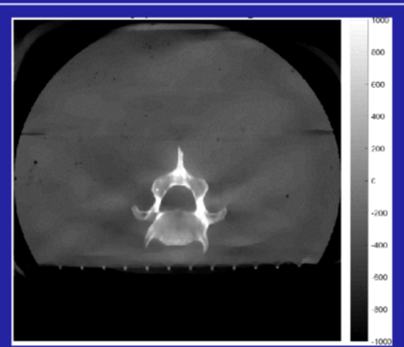
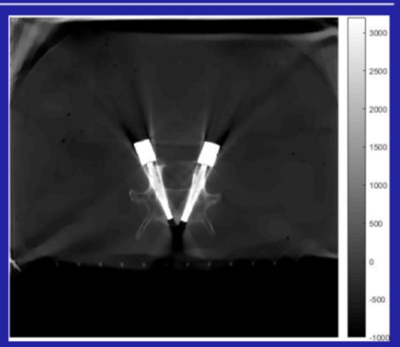
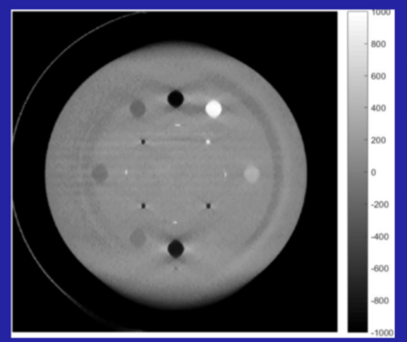
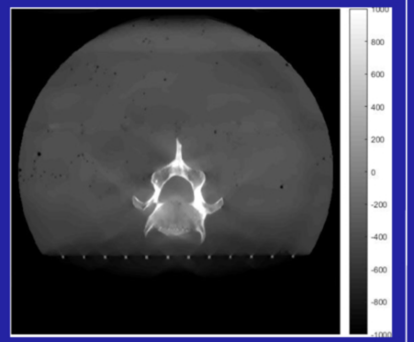
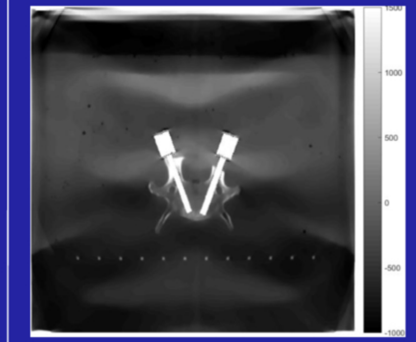
RESULTS:

The quantitative image analysis of the Catphan revealed that the double axial/coronal OLASC at 90 degrees and 90 projections per arc (180 projections total) reproduced the MTF curve of and resulted in a relatively low RMSE compared to the input Varian OBI CBCT generated image set. Furthermore, qualitative analysis using the anatomical phantom showed the double axial/coronal OLASC at 90 degrees and 90 projections per arc generated soft tissue to bone contrast that was diagnostic quality. Qualitative image analysis of the anatomical phantom with digitally added pedicle screws demonstrated that the triple axial obliques plus sagittal OLASC at 90 degrees and 90 projections per arc (270 projections total) generated a nearly photon starvation artifact free reconstruction of the pedicle screws.





TOP: RMSE of each double anatomical OLASC at 0.5 projections per degree and various arc lengths with the input Varian OBI CBCT. **BOTTOM**: MTF curves for double axial/coronal OLASCs at 0.5 degrees and various arc lengths.

	Catphan Phantom	Anatomical Phantom	Anatomical Phantom w/ Pedicle Screws
 **Axial Varian OBI CBCT**			
Double Axial/Coronal OLASC- 90 Degs/ 90 Projs per Arc			
Triple Axial Oblique plus Sagittal OLASC- 90 Degs/ 90 Projs per Arc			

ABOVE: Table of slices of reconstructions of the Catphan phantom and the anatomical phantom with or without pedicle screws for visual comparison.

CONCLUSIONS:

- Double axial/coronal OLASC at 90 degs/90 projs per arc optimum for RMSE/MTF and soft tissue to bone contrast
- Triple axial obliques + sagittal at 90 degs/90 projs per arc optimum for photon starvation artifact reduction

REFERENCES:

1. Patent: Banks SA, Bova FJ, Inventors; University of Florida Research Foundation, Inc.; 2014
2. *TIGRE: Tomographic Iterative GPU-based Reconstruction Toolbox;* Biguri, Ander; et. al.**;** CERN.